THE LATE HOLOCENE WHITECOURT METEORITE IMPACT CRATER: A LOW-ENERGY HYPERVELOCITY EVENT. R. S. Kofman[1], C. D. K. Herd[1], E. L. Walton[1], D. G. Froese[1]. [1]Department of Earth and Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, Alberta, Canada, T6G 2E3, rkofman@ualberta.ca

Introduction: Small impact events resulting in simple impact structures <100 m in diameter are common features recorded on the solid surfaces in our Solar System. Such structures are rare in Earth's impact cratering record and most are typically heavily modified by subsequent erosion or are found in remote locations. The recently discovered Whitecourt Meteorite Impact Crater (WMIC) provides significant contrast in that it is both well preserved and easily accessible. The level of preservation, age (<1.13 ka) [1] and associated meteorite fragments, scattered up to 70 m distance from the rim, suggest that this site will provide considerable data for the improvement of current models for similar structures.

The Crater: The WMIC target material consists primarily of gently northeastward dipping Quaternary deglacial sediments deposited during the retreat of the Laurentide Ice Sheet. The crater formed along a narrow Holocene terrace immediately adjacent an ephemeral stream (Figure 1) [1]. The soil profile in the area is classified as an Orthic Grey Luvisol resulting from the weathering of the parent diamict [2] and extends to depths of at least 2 m.

The crater shape is similar to other Barringer type (simple) structures. The bowl-shaped crater floor and crater walls do not appear to have undergone significant modification in recent history. A raised rim is only evident along the northeastern half of the crater where elevation is lowest. The southwest crater rim is 4 m higher than the northeast rim as a result of the local topography. The crater has a diameter of 36 m and a depth of 6 m as measured from a cross-section oriented parallel to the hill slope as obtained from a LiDAR-derived digital elevation model [1].

The subsurface stratigraphy at the center of the crater is presently constrained by two bore holes 4 m and 5.4 m deep. The local water table is below this depth. The stratigraphy consists of a 10 cm thick organic-rich silty soil sharply overlying a heterogeneous pebble diamict. The diamict includes clasts up to 10 cm in diameter in the upper 50 cm decreasing to 5 cm to a depth of ~2.9 m. At ~2.9 m there is a sharp transition to a clean medium sand, which continues uninterrupted to the base of the bore holes. A number of weathered meteorite fragments < 1 cm in diameter were recovered from a thin region immediately above the 2.9 m contact. No melt has been observed within or outside the crater.

A bore hole located midway up the northeastern crater wall includes a heterogeneous pebble diamict similar in colour and composition to that found at the base of the crater. It is observed to a depth of ~1.4 m. At this depth a sharp transition to a significantly darker and more homogeneous diamict is observed. Near the base of this bore hole, at ~2.6 m, a potentially gradational contact to a clean medium heavily iron-stained sand occurs. This sand is similar to that observed beneath the base of the crater. An obstruction encountered at ~2.65 m prevented further boring.

The Ejecta Blanket: A buried soil horizon was used to map the distribution of the ejecta blanket at the WMIC. The paleosol is typically 3 cm to 8 cm thick and varies between a charcoal rich O horizon to a dark Ah horizon (essentially an organic-rich massive sand). Charcoal collected from this layer provides the maximum age of the crater [1]. Aside from the meteorites found overlying the ejecta blanket and in the surrounding area no other meteoritic material has been observed.

Along the crater rim the ejecta consists of heavily pedoturbated Ae and Bt/C material ranging in thickness from ~0.20 m to ~0.85 m. The Ae horizon is primarily massive very-fine sands while the Bt/C is diamict. The contacts between the Ae and Bt/C material are sharp. The ejecta is well-preserved and shows little evidence of subsequent soil development. The areas of thickest continual coverage are observed along the regions of lowest elevation. Drilling by hand was performed across two lines transecting the crater, trending along 034º and 110º, and results were used to generate cross-sections revealing the distribution of the ejecta blanket. The range of the ejecta blanket along these transects is displayed in Figure 1.

The Meteorites: The meteorites collected from the WMIC, classified as type IIIAB iron [1], consist almost entirely of jagged shrapnel. The fragments collected outside the crater are slightly weathered and have no fusion crust or regmaglypts. They are all of mm to cm scale with masses typically in the tens of grams, the largest being 1.2 kg. All fragments associated with the ejecta blanket are found at the base of the modern soil overlying the ejecta. The fragments collected from the 2.9 m transition at the base of the crater are all < 1 cm in diameter, jagged, heavily weathered and do not appear to have undergone melting.

The current distribution of meteorites, shown in Figure 1, forms a 'half-elliptical' strewn field, having a semiminor and semimajor axis of approximately 50 m and 90 m respectively. The semimajor axis trends roughly along 235º. The crater is located at the southwest edge. The greatest concentration of meteorites is adjacent to the crater though no fragments have been found near the surface within the structure itself. The most distal meteorite is located 70 m east of the crater rim. A magnetic survey indicates that no significant buried mass is present within or around the crater.

Conclusions: The sharp contact observed at 2.9 m is interpreted as being the base of the transient crater [1]. The recent discovery of meteorite fragments immediately above this boundary reinforce this conclusion. Along the crater wall the transition from the pale heterogeneous diamict to the dark 'homogeneous' diamict is interpreted as representing the transition from allochthonous crater fill to autochthonous sediments. The transient crater therefore has a depth of ~9 m and a loosely constrained diameter of ~29 m.

The crater likely formed by the hypervelocity impact of a single large projectile as opposed to a swarm of smaller ones, as the latter would have resulted in a flatter-bottomed, shallower depression [3]. The present lack of observed melt or clearly shocked material and the presence of meteorite fragments at the base of the crater fill indicate that this was a low-energy hypervelocity event. The lack of ablated material on meteorite surfaces also supports a lower atmospheric transit velocity. It is likely that this crater is near the transition between penetration and hypervelocity impact structures.

The distribution of the ejecta blanket appears to be most strongly controlled by topography. The implication is that the impact trajectory was at a relatively steep angle. The influence of topography also makes trajectory determination more difficult. The level of preservation of the ejecta may indicate an age much younger than 1.13 ka. In addition the lack of meteoritic material (Ir-anomalies, melt, spherules, etc.) indicates that the projectile underwent little or no vaporization during impact.

There are two primary hypotheses for the formation of the strewn field: atmospheric fragmentation and explosive disruption during impact. If the strewn field was formed solely as a result of atmospheric fragmentation, the location of the crater with respect to the strewn field would suggest that the projectile struck while travelling along a relatively steep trajectory towards the southwest. The strewn field would appear to be primarily the result of a single major, low-altitude fragmentation event. The reason for the apparent truncation of the strewn field would remain elusive, though possibly related to the limits of the search techniques.

If the strewn field was formed solely as a result of the explosive disruption of the meteoroid during impact less constraints could be placed on the trajectory of the meteoroid. In this case the strewn field shape would be controlled primarily by local topography. Fragments ejected towards the southwest, where the crater rim elevation is greatest, would remain closest to the crater. Fragments ejected towards the northeast, where the crater rim elevation is lowest, would travel the furthest. In this case the apparent truncation of the strewn field could simply be a result of the energy of the impact and topography. Further investigation will be required to determine the most plausible hypothesis, though it is quite possibly a combination of both.

The WMIC represents an exceptional new resource for the impact cratering community. The pristine structure and associated meteorites and strewn field should provide new control points for current models. Not only is it among the smallest and youngest terrestrial hypervelocity impact structures, it is also likely very near to the lowest energy end-point of such structures. In addition the WMIC is also readily accessible making it an easy target for future research.

Acknowledgements: The authors would like to thank the Natural Sciences and Engineering Research Council of Canada (NSERC) - PGS M to R.S.K. and Discovery Grant 261740 to C.D.K.H. - and the Canadian Space Agency (CSA) - SSEP CARN grant to C.D.K.H. - for their generous support for this research project. The primary author would also like to thank Laurence Andriashek, Scott Harris, Christian Koeberl and Jay Melosh for their help.

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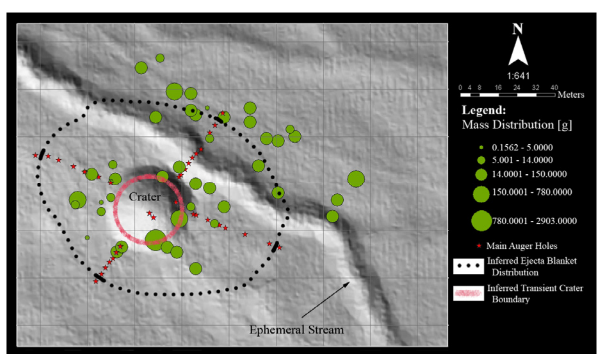

Figure 1: A map of the site based on bare-earth LiDAR data and field relationships.